Relationship of Solid Cattle Manure Placement Method to Nitrogen and Phosphorus Movement in a Black Chernozem

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1. INTRODUCTION

The expansion of the intensive livestock industry in western Canada has lead to subsequent concerns about the overloading of nitrogen (N) and phosphorus (P) nutrients in soil. In areas that receive high application rates of animal manures, elevated transport of particulate and dissolved P and N by water can be of concern in soils that are overloaded in nutrient (Carefoot and Whalen, 2003; Lee et al., 2003). For example, since the 1990's soil P levels in Manitoba have increased due to manure application and agricultural sources have been identified as responsible for supplying 15% of Manitoba's portion of the P loading into Lake Winnipeg (Barker, 2007).

Soil will retain a majority of the P and N applied as animal manure that is not removed by the crop through transformations such as immobilization, adsorption and precipitation. Manure application methods such as broadcasting and incorporation or subsurface injection of manure could have effects on the amounts of N and P that run off the surface or leach into the soil profile. Liquid hog manure (LHM) has proven to have very successful agronomic results when applied by subsurface injection (Mooleki et al., 2002). Similar to LHM injection, solid cattle manure (SCM) can now be applied using a direct injection system that utilizes a coulter opener and is "injected" into a furrow that is then closed behind the injection unit. The objective of this research was to investigate the effect of placement methods for solid cattle manure on N and P in run-off water in an annually cropped field.

2. MATERIALS AND METHODS

2.1. Site Description

The SCM injection study at Dixon was established in the spring of 2007 before spring seeding operations commenced with the first applications of SCM. The experiments were initiated on the southern half of a farm field (legal location NW 21-37-23-W2) located approximately 6.5 km west of the town of Humboldt adjacent to Saskatchewan Provincial Highway #5, within the Rural Municipality of Humboldt (Figure 3.1). The soil at this site belongs to the Cudworth Association and is a Black Chernozemic soil formed in calcareous, silty, lacustrine parent materials and having a loam surface texture

(Saskatchewan Soil Survey, 1989). Crops grown on the Dixon site were oats in 2007, canola in 2008 and oats in 2009.

2.2. Experimental Setup

The SCM field trial was set up as a randomized complete block design. Treatments were replicated four times at Dixon. The plot size of the SCM trials measured 6.1 m by 6.1 m. The control plot consists of no manure or fertilizer being applied and disturbance of the soil using the coulter openers of the SCM injector machine.

Solid cattle manure was applied using three application procedures; 1) broadcast application where SCM is applied on the soil surface (no incorporation), 2) broadcast and incorporated where SCM is applied on the soil surface and then incorporated using a disk, 3) subsurface injection, where SCM is subsurface injected using the PAMI Solid Cattle Manure Injector Machine in six subsurface trenches by 24 inch coulter openers spaced 30 cm apart applying SCM product 10-13 cm in depth. Eighteen inch closing wheels cover the exposed injection trench with soil. Commercial urea fertilizer (46-0-0) is banded into the soil using a small plot drill at a rate of 78 kg N ha^{-1}.

The rate of SCM being applied this study (3X) was equal to 300 kg total N ha^{-1}, at a rate of 60 tonnes ha^{-1}, and may be considered triple the recommended agronomic rate in line with the amount of N that would be recommended as fertilizer manure to meet a crop requirement.

2.3. Manure Applications

The SCM applied in the field trial at Dixon was obtained from the Poundmaker Feedlot, which is located approximately 8 km east of the town of Lanigan, SK. The manure was applied to the appropriate plots using the PAMI Solid Cattle Manure Injector Machine. Application rates of the SCM are listed in Table 2.1. The SCM was applied to the Dixon site on June 12 and 13, 2007 for the 2007 crop year. The SCM was applied to the Dixon site on May 10, 2008 for the 2008 crop year and May 20, 2009 for the 2009 crop year.

Table 2.1 Treatments in the solid cattle manure trials that were sampled for the thin section run-off study at the Dixon site.

Treatment†	**Sequence**	**N rate**	**Application method**
0 T ha^{-1}	control-disturbed	0 kg N ha^{-1}	with no incorporation, but disturbance
60.6 T ha^{-1}	3X	300 kg N ha^{-1}	cattle manure broadcast and incorporated
60.6 T ha^{-1}	3X	300 kg N ha^{-1}	cattle manure broadcast only
60.6 T ha^{-1}	3X	300 kg N ha^{-1}	cattle manure subsurface injected
urea fertilizer	U	78 kg N ha^{-1}	banded urea 46-0-0 fertilizer

† Application rate based on wet weight.

2.4. Thin Section (Slab) Collection

Soil thin section slabs were collected in the falls of 2008 and 2009 after harvest operations had concluded for each of those crop years. In each designated plot, a small trench was excavated to expose a 30 cm by 50 cm section of soil. A crosscut handsaw was used to cut the 30 cm by 50 cm soil section at an approximate depth of 5-10 cm (Figure 2.1). Once the thin section had been severed, a plastic sheet was inserted into the severed section in order to remove the thin section slab as intact as possible taking care not to fracture the 30 cm by 50 cm thin section in separate fragments (Figure 2.2). The thin section slab was placed in a plastic storage container for transportation back to the University of Saskatchewan for storage at -20 °C. The thin section consisted of the upper 5-10 cm of soil plus the accompanying crop residues.

Figure 2.1. Photograph of Thin section monolith being extracted using a crosscut saw.

Figure 2.2. Photograph depicting insertion of a plastic sheet to extract the thin section monolith from the soil surface.

2.5. Determination of Nitrogen and Phosphorus in Soil Thin Section Runoff

The soil thin section slab monoliths were placed inside insulated plywood boxes designed to slow the rapid thawing of the soil thin section so as to allow the added snowcover to infiltrate the subsurface of the soil and not just run off the soil surface. Approximately 2 kg of snow representing about 7.5 cm of snow cover in a field was added to the thin section slab surface. (Figure 2.3).

Fig. 2.3. Thawing thin section slab with snow applied.

Fig. 2.4. Frozen thin section slab with water being applied.

The rear of the insulated plywood boxes was elevated to a position of 5 degrees to allow leachate runoff to occur. The boxes were lined with plastic sheets directing snowmelt runoff and leachate to be collected in a plastic bucket.

Frozen thin section slabs were subjected to water being applied on the frozen surface (Figure 2.4). The frozen slabs were placed in insulated boxes lined with plastic to capture the runoff. The snowmelt runoff and leachate from the thawing thin section slabs and the water runoff from the frozen thin sections was stored at -20 $^{\circ}$C until samples were filtered using milipore 45 µm glass filters. All samples were analyzed for soil extractable nitrate-nitrogen (NO_3-N) and ortho-phosphorus (P) using a Technicon™ automated colorimetry analyzer.

3. RESULTS AND DISCUSSION

3.1. Snowmelt Thawing Thin Section Slabs

Snowmelt conducted on thin section slabs obtained in the fall of 2008 showed that runoff and leachate removal of NO_3-N was greatest for the urea treatment (Figure 3.1). The broadcast and incorporated manure treatment had a greater amount of NO_3-N (0.61 kg ha^{-1}) removal compared to the broadcast alone and subsurface injected treatments which showed 0.41 kg ha^{-1} of runoff and leachate NO_3-N. These differences were not significantly different at $p \leq 0.10$.

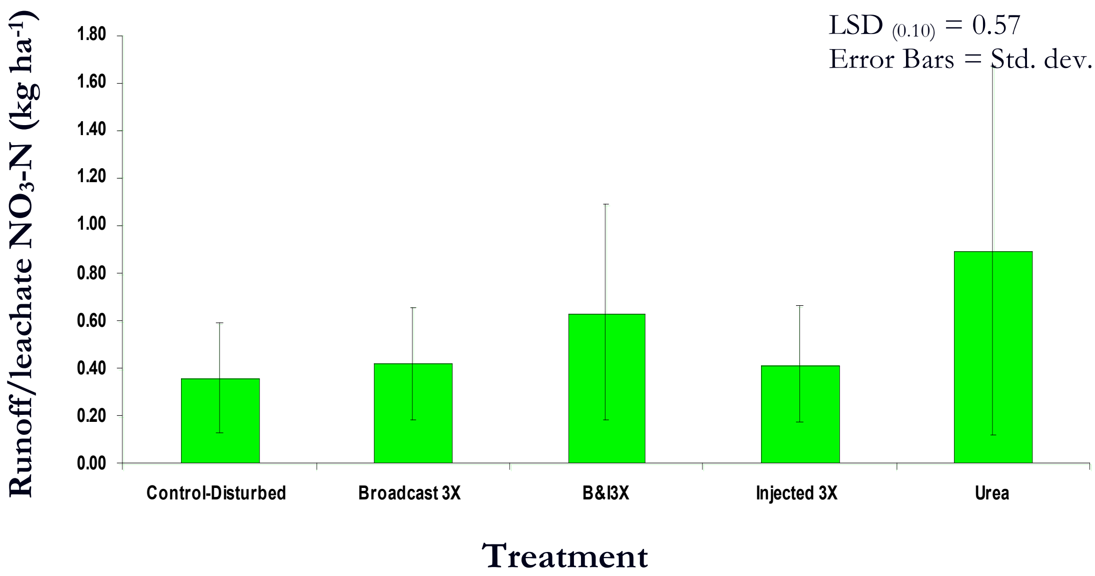

Figure 3.1. Fall 2008 snowmelt runoff and leachate nitrate-nitrogen exported from thawing soil thin section slabs.

Runoff and leachate phosphorus increased from the broadcast alone treatment to the broadcast and incorporated and the subsurface injected treatments, however the differences were not significant at $p \leq 0.10$. Subsurface injection treatment removed 0.30 kg P ha^{-1} (Figure 3.2).

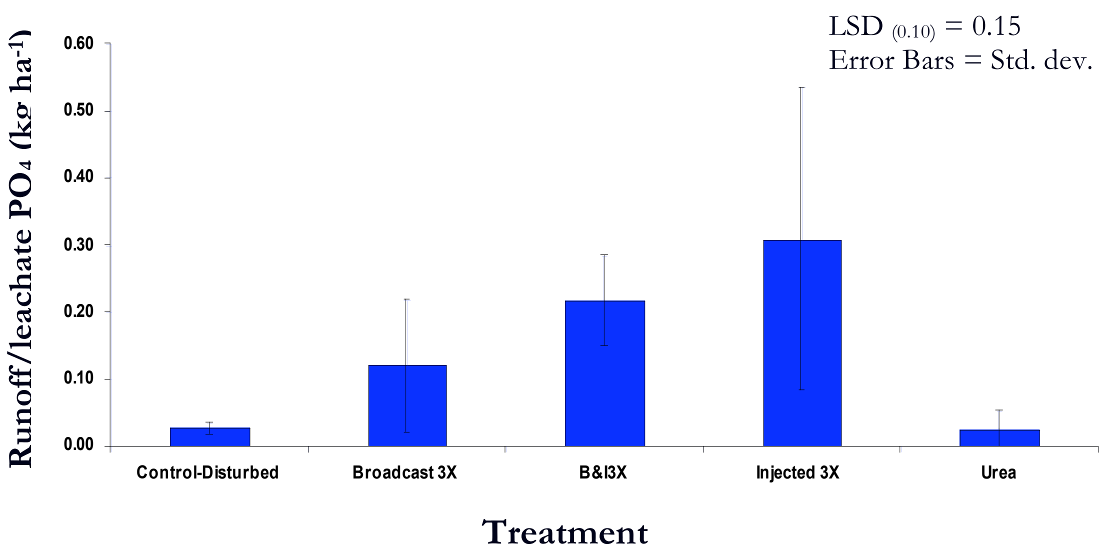

Figure 3.2. Fall 2008 snowmelt runoff and leachate ortho-phosphate exported from thawing soil thin section slabs.

Snowmelt conducted on thin section slabs obtained in the fall of 2009 showed that the broadcast & incorporated treatment had the highest NO_3-N removal of 3.1 kg ha^{-1}, while NO_3-N removal in the broadcast alone and injected treatments were similar (Figure 3.3).

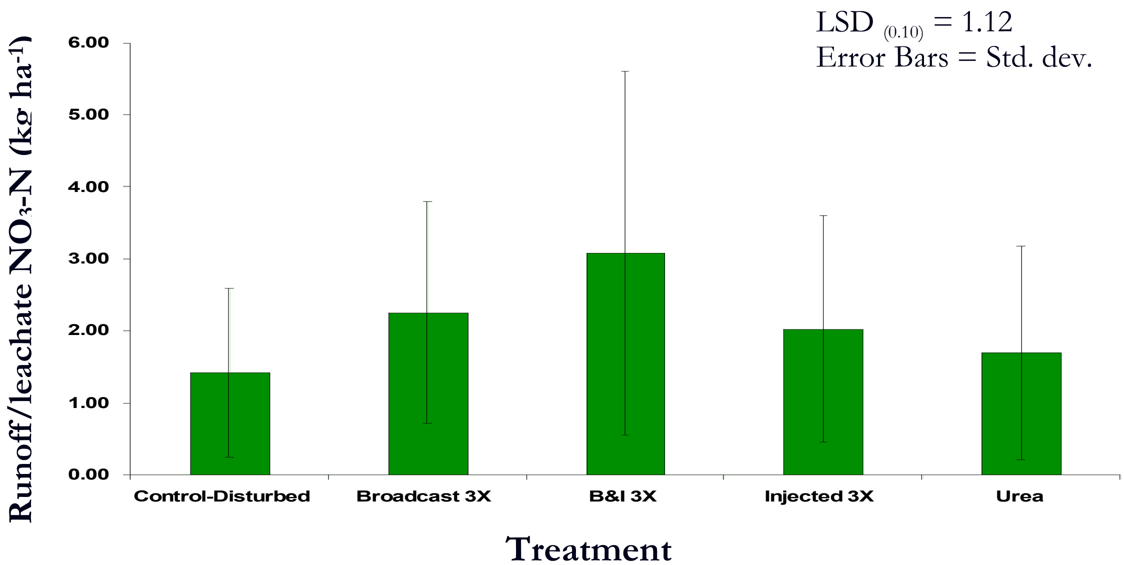

Figure 3.3. Fall 2009 snowmelt runoff and leachate nitrate-nitrogen exported from thawing soil thin section slabs.

The broadcast and incorporated and injected treatments had the greatest removal of phosphate of 0.50 kg ha^{-1}, however this was not statistically different ($p \leq 0.10$) from the phosphate removed in the broadcast alone treatment (Figure 3.4).

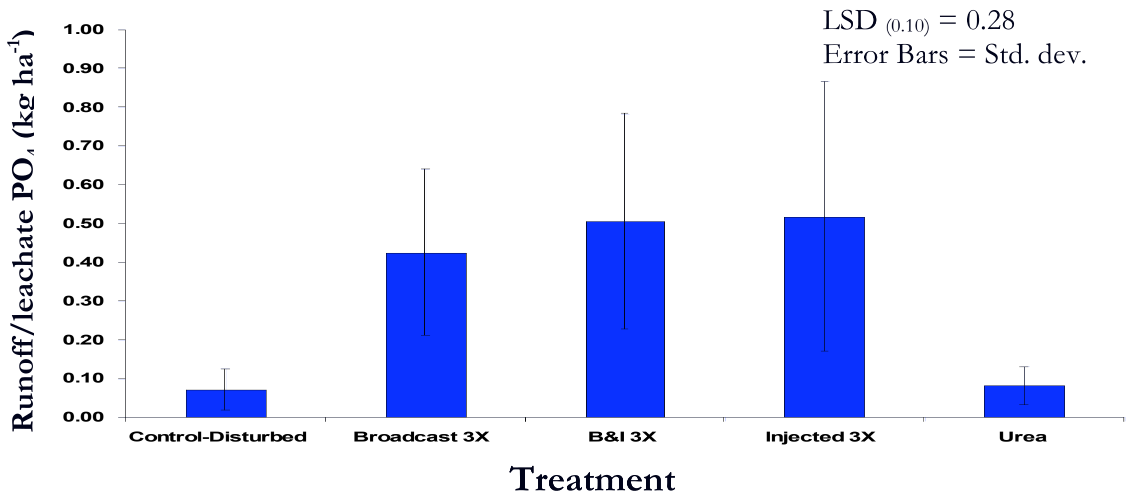

Figure 3.4. Fall 2009 snowmelt runoff and leachate ortho-phosphate exported from thawing soil thin section slabs.

Overall in 2009, the amount of NO_3-N and P removed was greater than what was removed in 2008. Nitrate-nitrogen export in the simulated snowmelt on thawing soil was about 0.5 kg ha^{-1} in the first year and increased to 2 kg ha^{-1} in the second year of manure application. However, there was found to be no significant effect in NO_3-N removal rates between the three manure application methods. The application of SCM significantly increased ortho-P export compared to the control treatment. More manure nutrients had been added to the field plots and this was reflected in the amounts of NO_3-N and P that was removed by runoff and leaching with snow.

3.2. Water Runoff From Frozen Thin Section Slabs

In the fall 2009 samples, the broadcast and incorporated treatment showed the most export of NO_3-N in the runoff over the frozen soil thin section slabs (Figure 3.5). The broadcast alone and subsurface incorporated treatments had similar water runoff removing about 0.20 kg NO_3-N ha^{-1}. The three SCM treatments were not significantly different ($p \leq 0.10$) from one another, however they were significantly different from the unmanured control-disturbed treatment.

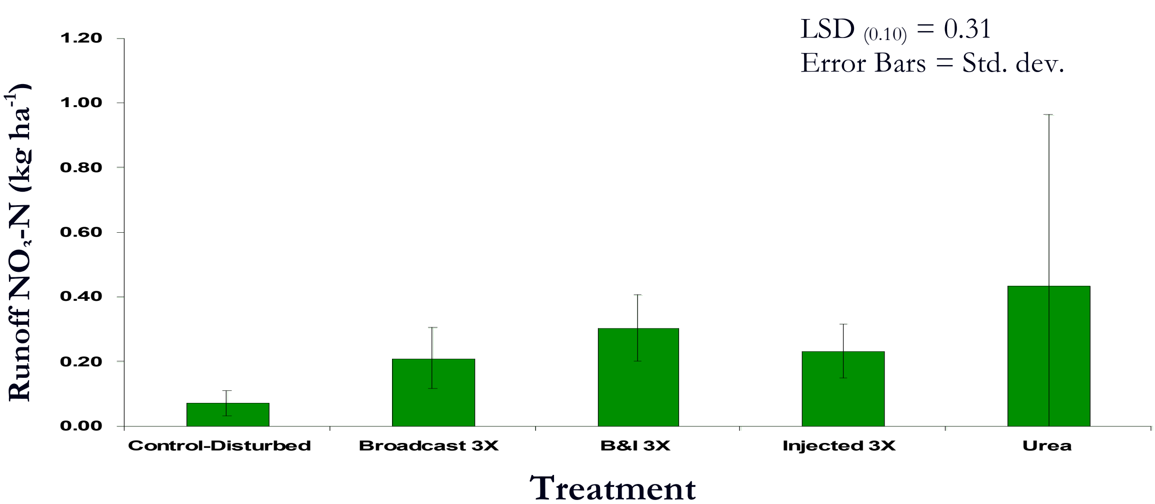

Figure 3.5. Fall 2009 water runoff nitrate-nitrogen exported from frozen thin section slabs.

There were no significant differences in ortho-P export in the runoff from the fall 2009 soil thin section slabs amongst the three SCM treatments (Figure 3.6). Although the broadcast alone, broadcast and incorporated and subsurface injected SCM treatments were significantly different from the control-disturbed treatment, there was no significant differences ($p \leq 0.10$) between the manure treatments and the urea fertilizer treatment. The amounts of NO_3-N and ortho-P exported in water runoff across frozen thin section slabs was much less than the NO_3-N and ortho-P exported through melting snow on thawing soil thin sections.

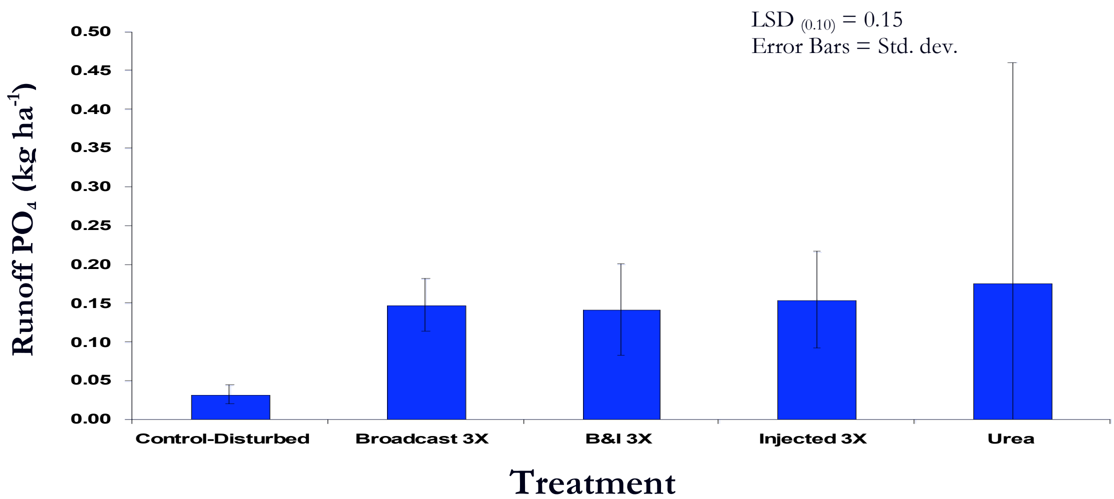

Figure 3.6. Fall 2009 water runoff ortho-phosphate exported from frozen thin section slabs.

4. SUMMARY AND CONCLUSIONS

The addition of SCM to cultivated soil increased nitrate and phosphate export in water. The increase in the amount of NO3-N and ortho-P that was exported off thawing thin section soil slabs through snowmelt runoff and leachate was much greater than what was exported in runoff water from frozen thin section slabs. Nutrient export was not affected by the three solid cattle manure placement methods under simulation of water running across the surface of frozen soil. In-soil subsurface placement of solid cattle manure may increase phosphate export when snowmelt takes place on a thawing soil compared to broadcasting manure. The amount of NO_3-N and P removal increased from the first to the second year of application. The placement of manure under the soil surface in concentrated bands may make it easier for the phosphate to be solubilized thus facilitating transport through a combination of runoff and percolation of leached water from spring snowmelt conditions.

5. REFERENCES CITED

Barker, B. 2007. Managing phosphorus based manure inputs. Top Crop Manager. December 2007. 33:

Carefoot, J. P. and J.K.Whalen. 2003. Phosphorus concentrations in subsurface water as influenced by cropping systems and fertilizer sources. Can. J. Soil Sci. 83: 203–212.

Mooleki, S.P., Schoenau, J.J., Hultgreen, G., Wen, G., and Charles, J.L. 2002. Effect of rate, frequency and method of liquid swine manure application on soil nitrogen availability, crop performance and N use efficiency in east-central Saskatchewan. Canadian J. of Soil Sci. 82(4): 457-467.

Saskatchewan Soil Survey. 1989. Rural Municipality of Humboldt No. 370. Preliminary soil map and report. Saskatchewan Institute of Pedology, University of Saskatchewan, Saskatoon, SK, Canada.